Subsea excavation and suction device

The present invention concerns a device for subsea excavating and movement of solid material. More precisely it concerns a subsea excavating and suction device with a suction head with means to disintegrate solid material, mounted on a controllable arm

Background

When performing subsea operations there is often a need to move solid material, commonly denoted "bulk material" or "bulk". This may occur during levelling a terrain, trenching of ditches, embedment of pipes and cables or removal of ballast gravel. Corresponding needs may also occur in connection with work at or near a quay, harbour or dam installation.

In many cases the bulk material is comprised by compact silt, clay or other hard bulk materials which involves a number of challenges, primarily due to the hardness of the material which make it difficult to disintegrate.

At the same time the bulk material includes fine particles that lead to reduced visibility when dispersed or dissolved in water. Furthermore it may be a problem that the material is broken into rather blocks that are hard to move. These problems are added to high demands of precision with respect to the work performed, in order to e.g. avoid damage to fragile installations.

Prior art

US patent No. 4,479,741 (Berti, 1982) describes a trencher, i.e. a device designed to remove sediment along a subsea pipe or penstock. The patent describes a full track type vehicle with preferably separate ejectors at each side of the pipe or penstock. The ejectors are intended to suck up and blow away sediment along the pipe or penstock in question. The ejectors have a mouthpiece that is telescopically extendable in a vertical direction and with a cross-sectional area that corresponds to the cross-sectional area of the hose or pipe through which the sediment will be blown.

Norwegian patent No. 311 639 (PCT/NO01/00142) discloses a device for the transportation of sediment, including comparatively large rocks, under water. The device comprises a belt or wheel based vehicle with an ejector powered suction hose, with a suction head arranged on a hydraulically controllable arm. A vital feature of this prior art device is the design of the suction hose or pipe with a substantially even cross-section throughout its length and that the inlet opening of the suction head under no circumstances must be larger than the mentioned cross-section, since this would involve a high risk of large particles getting stuck in the hose or pipe. It is indicated that the suction head may be furnished with nozzles to provide jet streams of water for loosening compact sediment/ bulk material.

Norwegian patent application No. 2001 6361 (PCT/NO02/00491) describes a suction head for dredging with the characterizing feature of comprising two separate inlet openings, of which one is intended to suck up a mixture of sediment an d water while the other is arranged in a manner to avoid contact with the seafloor and therefore will suck in water only. The construction provides an automatic control of the suction power in the suction head dependent on the concentration of solid material that at each time is present, thereby minimizing the risk of blocking the suction head.

Furthermore there is known in the literature ROV based devices for subsea transportation or movement of solid material/ sediment. The technical solutions related to the material transport for these devices generally follow one of the alternatives for movement of solid material mentioned above. There are e.g. known devices where so-called Zip pumps set up the suction force in a suction hose used for the purpose intended.

With respect to land based machines for moving bulk material, there have been suggested excavators with varying shapes and varying degrees of freedom for the scoop/ grab, normally by means of hydraulically controlled manoeuvre arms. Vertical rotation about a horizontal axis is the most common movement for an excavator grab, but there are also embodiments that allow sideways rotation about a vertical axis and there are variants (Menzimuck) where one element of the manoeuvre arm is telescopic, allowing the grab to move back and forth along the telescopic axis. There are also for subsea use developed "simple" excavators intended for moving material strictly mechanically with a scoop or grab, not making use of jet nozzles or suction hoses/ ejectors.

Common for all known devices for subsea mass or bulk transportation is a lack of versatility with respect to use for different purposes and for solid material of varying character. For tasks like moving substantial amounts of sediment or other solid material collected in a pile and comprising both loose rocks and particles of highly varying size on one hand and compact clay on the other hand, none of the prior art devices are particularly well suited.

Objectives

The objective of the present invention is to provide a ubsea excavating and suction device with a suction head that has an improved ability to disintegrate hard and ductile materials like clay, and which is able to move the loosened or excavated material a certain distance, e.g. to a subsea "land" fill.

It is a further objective of the invention that the device shall be versatile in the sense that it is capable of working with material of highly varying nature and efficient with respect to the volume capacity that it is able to excavate and move in a certain period of time.

It is a still further objective that excavation of fine grain particulate materials can be done in a manner with which the visibility in the water is not significantly reduced.

It is a still further objective of the invention that the device may be used for an exact shaping of the terrain, e.g. for levelling prior to installation of a sea floor structure, trenching of ditches, etc.

The present invention

The invention comprises a device as defined by claim 1.

Preferred embodiments of the invention are disclosed by the dependent claims.

The invention makes it possible to "dig" quickly even in very compact clay and sediment/ bulk material with varying nature and particle size. In order to achieve this the device according to the invention comprises a suction head mounted to an hydraulic arm, the suction head having an inlet opening with a cross-sectional area that is larger than the cross-sectional area of the suction hose through which the solid material is removed, while at the same time being provided with mechanical and hydraulic means to disintegrate the solid (bulk) material.

When e.g. used in compact clay the device according to the invention utilizes hydraulic means in the form of water jet nozzles, hereinafter dented primary jet nozzles, arranged along substantially the entire periphery f the inlet opening. These primary jet nozzles are preferably arranged in a diction substantially perpendicular to the inlet opening, and the liquid (water) from these jet nozzles will be able to cut through clay and other compact material and break loose pieces of same.

In order to have maximum utility of the water the inlet opening of the suction head is brought by means of the controller arm to a close contact with the material to be removed, so that the nozzle orifices are presses against or into the material. In this connection it is vital that the suction head is movably attached to the controller arm, preferably with several degrees of freedom of movement. It is particularly preferred that the suction head have the ability to rotate along an imaginary circle periphery.

In addition the suction head comprises mechanical means for disintegration of sediment/ bulk material in the form of at least one rigid bar across the inlet opening, so that the suction head with an impact force may be pushed against the material to be disintegrated.

It is also, as previously mentioned, strongly preferred that the suction head and particularly whole or parts f the edges 6_1- 6_4 around the inlet opening is made in a material and with a thickness enabling it to function as a mechanical tool for disintegration of material to be removed. It is particularly preferred that whole or a part of the edges 6_1- 6_4 around the inlet opening is made with an extending edge or structure, generally with a wedge-like profile, and that the nozzles are integrated in such an extending edge.

With the characterizing features according to the invention one may, utilizing a suction head with a shape that is particularly adapted to the task in question and with a cross-sectional area that is larger than what is convenient to apply for the suction hose through which the material is to be

removed, belabour the material hydraulically and mechanically to break loose e.g. clay. The fact that the primary jet nozzles may be forced into highly compact material enables the break-up of even very compact clay with a moderate water pressure. This ability is enhanced even more if the primary nozzles are integrated in or shaped as "teeth" or as a breaking, wedge-like edge that is able to penetrate the material in question.

The feature that the cross-sectional area is larger than and preferably significantly larger than the cross-sectional area of the suction hose that is used for conveying the material, allows a particularly quick excavation and material transportation. Such a solution requires, however, that a quick and efficient disintegration of sediment may be conducted, which as far as the inventors know, not has been possible to obtain hitherto.

The present invention in more detail

Figure 1 is a front view of an excavation and suction device according to the present invention.
Figure 2 is a side view of the suction head of Figure 1.
Figure 3 is a front view of an alternative embodiment of an excavation and suction device according to the invention.
Figure 4 is a front view of still another embodiment of an excavation and suction device according to the present invention.
Figures 5a, 5b shows in magnification two variants of nozzles included in the device according to the invention.
Figure 6 is a side view of a fourth embodiment of an excavation and suction device according to the present invention.
Figure 7 is a side view of an assembly of a tool support (a chassis) and an excavation and suction device.
Figure 8 is a top view of the assembly of Figure 7.

Figure 1 is a schematic front view of a preferred embodiment of a suction head 1 that constitutes the central element of an excavating and suction device according to the present invention. At the outer, free end of the suction head (lowermost part of the drawing) the inlet opening 3 is shown divided in 8 mainly equal inlet sections $3_1 - 3_8$ (an arbitrary one designated 3_i) by three short bars 4_1- 4_3 and a longer crossbar 5 arranged perpendicular to the bars 4_1- 4_3, and by the outer walls 6_1 - 6_4 of the suction head. Around the edges of all inlet sections 3_i of the suction head are shown a number of primary jet nozzles 7_i. The primary jet nozzles are thus arranged partly on the outer walls 6_i (erroneously "5_i" in the original) of the suction head and partly on the bars 4_i and 5. In the uppermost part of Figure 1 is shown a supply pipe 8 for pressurized water which is connected to suction head 1 via a swivel 9 and branched to each of the afore mentioned nozzles 7i by means of a number of smaller pressure water pipes. Figure 1 also shows a suction hose 10 that over a joint 11

is connected to an opening 12 at the back f the suction head 1. Between the suction hose 10 and the supply pipe 8 is shown a controller arm 13 that is attached to the suction head 1 by a hinged connection 14. The illustration of this in Figure 1 is somewhat simplified as the hinge 14 will normally comprise two separate axes that receives a supporting arm and a controller arm respectively, so that the suction head may be turned back and forth by hydraulically extending and contracting the controller arm relatively to the supporting arm.

In Figure 1 the primary nozzles are shown with a fixed mutual distance. This may be a convenient arrangement, but is certainly not a requirement. Often it will be desirable that the primary nozzles 7i along the lowermost edge 6_3 of the suction head are small nozzles that are arranged very close to one another so that they cut a plane, smooth surface. Other of the primary nozzles may be larger and arranged at a larger mutual distance from one another.

A particularly "cutting" effect may be obtained by the primary nozzles 7_i at the lowermost edge 6_3 if they are arranged with an inclination (not shown) compared to the normal direction of movement for the suction head 1 under work, said direction of movement being perpendicular or substantially perpendicular to the surface defined by the edges 6_1–6_4 around the inlet opening. Denoting the walls or surfaces of the suction head that ends in the edges 6_2 and 6_4 respectively for the side walls of the suction head, the primary jet nozzles 7_i positioned along lower edge 6_3 that are closer to edge 6_2 than to edge 6_4, may be angled away from the side wall comprising edge 6_2 and thus against the side wall comprising edge 6_4. Correspondingly may the primary jet nozzles 7_i positioned along lower edge 6_3 that are closer to edge 6_4 than to edge 6_2, may be angled away from the side wall comprising edge 6_4 and thus against the side wall comprising edge 6_2. If said primary nozzles 7_i are positioned in a common plane, the jets from same nozzles 7_i along the edge 6_3 will describe a continuous surface when the suction head is moved forward in a linear manner. It is obvious that also the primary jet nozzles 7_i along e.g. the upper edge 6_1 may be angled in a corresponding way.

Another way of obtaining such a cutting effect is by directing all of or some of the primary jet nozzles 7_i downwardly inclined compared to an axis perpendicular to the inlet opening, e.g. with an inclination of 10 degrees or more compared to such an axis.

The suction head 1 may be furnished with mechanical means in the form of a partition wall 14 or the like to lead the solid particles in the direction of the outlet opening 12.

Figure 2 provides a side view of the suction head of Figure 1. In Figure 2 the nozzles 7 is seen integrated in or designed as teeth 16 extending from the edge 6 of the suction head. With "extending" is meant having a direction mainly perpendicular to the surface defined by the inlet opening 3 of the suction head 1. It should, however, be noted that even when the suction head 1 is provide with extending teeth 16, primary nozzles 7 may also or alternatively be arranged between such teeth. Not all primary nozzles 7 have to be uniformly oriented. A majority of the nozzles

along the upper and lower edge may e.g. have a uniform orientation in order to provide parallel jets perpendicular to the inlet opening while every fourth or every fifth nozzle 7_i at the upper edge 6_1 may have an orientation allowing these nozzles to provide downward inclined jets in front of the inlet opening while every fourth or fifth nozzle at the lower edge may have an orientation allowing these nozzles to provide upward inclined jets in front of the inlet opening.

Figure 3 shows an alternative embodiment of the device according to the invention, with the characterizing feature of a particularly wide suction head 31. On the other hand the height of the inlet opening is reduced so that the total area of the inlet opening does not become too large compared to the cross-section of the suction hose, which would have led to a low velocity through the inlet opening and a correspondingly low suction ability. As disclosed by Figure 3 there are only bars 4_1 - 4_6 in one direction, no crossbars horizontally.

Figure 4 shows the "opposite" variant to Figure 3, i.e. a particularly narrow suction head 41 that has a particularly large height. The width of this suction head may typically be adapted to a particular purpose, like the width of a ditch for a pipe to be embedded in the sea floor. Figure 4 shows only horizontal bars and no vertical crossbars. The area of the inlet opening compared to the area of the suction head are of the same magnitude for all three embodiments shown in Figures 1, 3 and 4.

With all the three described embodiments of the invention the bars 4_i, 5_i serve a double purpose. Firstly they constitute a grating that ensures that no particles with a least cross-sectional dimension larger than the cross-section of each inlet section 3_i may be sucked into suction head 1. The bars thus have character of a filter. Secondly they have the more active character of constituting parts of a tool for hydraulic and mechanic disintegration of the sediment or bulk material that is to be moved.

The distance between the each bar 4_i and 5_i respectively is preferably chosen such that the cross-sectional area of any inlet opening 3_i is less then, or at least not larger than, the cross-sectional area of the outlet opening 12 from the suction head.

In addition to the primary jet nozzles 7_i that disintegrate material mainly outside the suction head 31, there may be arranged secondary jet nozzles to provide water jet streams mainly across the direction of movement for water and solid material through the suction head, thereby providing an additional disintegration of the material inside the suction head. Normally such secondary nozzles will be arranged in one or more rows across the direction of movement for the material through the suction head and preferably with at least one such row near the inlet opening.

One or more secondary jet nozzles may be arranged particularly in the vicinity of the outlet opening, to disintegrate any long and narrow particles that might pass through an inlet section and

that due to its length might not be able to pass through the joint 11 where the suction hose is attached.

By any one of the discussed embodiments there may within the suction head be arranged nozzles that are directed mainly from the inlet opening towards the outlet opening to facilitate transportation of particles in said direction. Such nozzles may be denoted tertiary nozzles as their aim of facilitating transportation through the suction head is different from the aim of the primary and secondary nozzles, to disintegrate the material.

Figures 5a-b show to variants of jet nozzles, as the variant of Fig. 6a comprises an extending wedge-like edge or correspondingly extending teeth 16, (continuously or discontinuously) in a direction perpendicular to the plane of the paper, while the variant according to Fig. 6b only have borings 17 (one shown) through the wall of a pressure water supply pipe 18 that in Fig. 6 extends mainly perpendicular to the paper plane. In the shown embodiments the profile of the pressure water supply pipe or pipes 18 are circular. There is, however, fully possible to use pipes with an oval profile which may also be preferable in order to let the pipes occupy as little space as possible in a certain direction within the suction head or to increase the rigidity of the pipes in a certain direction.

Figure 6 shows a particular variant of a suction head 61 according to the invention, a suction head that is tailor made to recover a pipe 19 in a ditch 20 filled with loose clay or the like which is comparatively easy to remove. The inlet opening of suction head 41 (61?) comprises areas at several sides of the head and the cross-sectional area of the inlet opening is significantly larger than for more normal embodiments of the suction head. In addition the suction hose 10' is extended within the suction head in order to suck up material from the lower part of the suction head.

Figure 7 shows an assembly in which the device according to the invention is mounted on or comprises a full track chassis 22. It is indicated that the device is mounted with a gear rim or similarly pivotal platform 23 in order to increase its reach and applicability. At the outlet end of suction hose 10, that has a substantially uniform cross-section throughout its length, a diffuser shaped pipe stub 24 contributing to a reduced loss in the hose is arranged. This is a preferred feature with the device according to the invention.

Figure 8 is a top view of the assembly of Figure 7. In Figure 8 is shown how the diffuser shaped pipe stub 24 may be pivoted between two or more different positions in order to obtain a greater versatility with respect to the direction with which the material is discharged. It is obvious that the feature shown in Figure 9 may also be applied when the outlet pipe stub is not diffuser shaped.

The bars may be manufactured in many different shapes and materials. A particular kind of bar is one where the pressure water pipe as such is manufactured in a material, a thickness and with a profile suited to function as bars. It should be noted that it is not required that the pressure water

pipes have a circular cross-section, such pipes can also have an oval cross-section, rhomb shaped cross-section, or other cross-sectional shapes so that they e.g. occupy less space in a certain direction or have a particular rigidity (flexural strength) in a certain direction. In general the pressure water pipes supplying water to the nozzles will be designed as part of the suction head and thereby contribute to rigidity and strength of the latter.

The orifice of the outlet opening 12 is typically rounded so that the frictional loss becomes as small as possible.

It is desirable in order to be able to work rapidly that the cross-section of the inlet opening is larger than the cross-section of the outlet opening. The ratio between these two areas should however not be too large. It is thus preferred that the ratio between these two areas is chosen such that the average water velocity through the inlet opening is at least 30 % of the water velocity through the outlet opening, and more preferred at least 50 % of the velocity through the outlet opening.

In order to further optimize the excavation and suction operation the suction head may have also a sideways movable joint (tilt or rotation) corresponding to the shovels used e.g. by landscape gardeners, and/ or the controller arm may be furnished with a telescopic element so that the suction head may readily be moved along a straight line.

The suction head may be designed in a number of different ways according to the actual tasks. For levelling a suction head that is several meters wide but with a very low inlet opening, e.g. lower than 20 cm, may be used. On the other hand, for ditching or trenching a suction head that is quite narrow but very high may be applied. The ditch and thus the width of the suction head need not be significantly wider than the cable or pipe diameter. The suction hose 10 and the supply pipe 8 for pressurized water are connected to the suction head 1 in a flexible or hinged way in order to allow the suction head its desired freedom of movement. The connection may vary with different designs of the pattern of movement for the suction head. For a suction head that may be pivoted around an axis a swivel will typically be used. A flexible hose between the suction head and a rigid outlet pipe may be used as an alternative to the flexible suction hose 10. If the controller arm 13 comprises a telescopic element, also the outlet pipe 10 will typically comprise such a telescopic element in the same region.

The suction in the suction hose 10 may be set up by means of one or more ejector nozzles arranged outside the cross-section of the suction hose so that the cross-sectional area is constant. It may thus be avoided that rocks or other large objects get stuck. The outlet that preferably is localized behind a chassis or a tool support may be furnished with a diffuser (tapered extension) to save energy. It is furthermore an advantage if the outlet/ diffuser as arranged in a way allowing it to be turned from side to side. By such an arrangement the direction of the material discharged may be controlled in

relation to the direction of stream in the water so that the visibility is largely maintained. Typically the diameter of the suction hose will be in the range 200 – 350 mm.

When above stated that the suction hose 10 is connected to the outlet opening of suction head 1, it is still within the frame of the present invention that such suction hose is comprised by a rigid, hinged structure that possibly constitutes an integrated part of an ejector used to set up the desired suction in the suction head.

It is furthermore implied that the source for pressurized water may be either a reservoir that is under pressure or water that is pressurized by means of a suitable pump when transported from the reservoir to the nozzles.